The writer also computed the phases of this eclipse for Mt. Hamilton, California, by the above method, with the following results, in Pacific standard time:

Begins, $6^h\ 09^m\ 41^s$, A. M.
Ends, $7^h\ 46^m\ 54^s$, A. M.

CHEHALIS, LEWIS COUNTY, WASHINGTON, March 14, 1891.

ON THE THERMOMETRIC CHRONOMETER OF THE LICK OBSERVATORY.

By A. O. LEUSCHNER.

The so-called thermometric chronometer (C. FRODSHAM & Co., 0008), of the Lick Observatory, is neither always a sidereal chronometer, nor does it always give mean solar time. It differs from other chronometers, inasmuch as it has no compensation whatever. Accordingly, the slightest change of temperature will produce a perceptible change in its daily rate. In February, 1889, when the first determinations of the rate of this chronometer were made for the purpose of finding its temperature coefficient, it gained on mean solar time in the neighborhood of six minutes per day, or about two minutes on sidereal time. In June, however, owing to the gradual increase in temperature, it was *losing* on sidereal time about three minutes per day. At this point the observations were discontinued, as the material on hand was deemed sufficient for the purpose of finding the temperature-coefficient.

I shall not here attempt to give a complete discussion of the investigations, for the final results have not, as yet, been attained, but, complying with a request of Professor HOLDEN, who thinks that the members of our Society may be interested to learn something about the odd behavior of uncompensated chronometers, I shall roughly sketch the nature of the preliminary reductions, and state the approximate results thereby obtained.

As it happened that during the winter just passed I had to conduct the practical exercises of a class in "Least Squares," I thought that the class might profit by a reduction of my observations, although there are other and simpler methods, by means of which approximations to the temperature-coefficient might have

been obtained. In order to learn, at the same time, something about the nature of the time-factor and about that of the barometer-coefficient, it was found expedient, to immediately start with the equations of condition in the well-known form proposed by M. IVON VILLARCEAU:

$$R = R_0 + a\,[T - T_0] + b\,[t - t_0] + c\,[B - B_0] + \ldots,$$

powers beyond the first being neglected; where $\left\{ \begin{matrix} R \\ R_0 \end{matrix} \right\}$ = mean daily rate at the time $\left\{ \begin{matrix} T \\ T_0 \end{matrix} \right\}$ at a temperature of $\left\{ \begin{matrix} t \\ t_0 \end{matrix} \right\}$ degrees (Celsius) and at a pressure of $\left\{ \begin{matrix} B \\ B_0 \end{matrix} \right\} \frac{1}{10}$ inches,

a = the time-factor,

b = the temperature-coefficient,

c = the barometer-coefficient.

R, T, t and B being observed quantities, four normal equations had to be formed for the determination of the unknown quantities R_0, a, b and c.

As the observations extended through nearly four months, and as the number of equations of condition that can be formed from comparisons on N successive days is (N—1), it would have been too laborious a task for each one of the beginners to carry out the entire problem (normal rates not having been formed before hand). The material was, therefore, divided into groups of from ten to fifteen days each, and the groups then divided among the students. Thus each computer obtained the four constants, independently of the others.

Before making known the results it may be well to shortly state, how in the equations of condition the terms t and B were formed, as it then will become apparent why the results obtained by this reduction cannot be considered to be final. At the Lick Observatory, as at many other stations where meteorological observations are made, the mean daily temperature is obtained by taking one-fourth of the sum of the thermometer readings made at 7 A. M., 2 P. M., and twice that made at 9 A. M. The chronometer comparisons were made at 12 A. M., and the rate was taken from one day noon to noon of the next day. Thus the daily rate depended on the temperatures of two days. It is evident that the rate was independent of the 7 A. M. reading of the

first day and of the 9 P. M. reading of the second. By recombining, however, the different readings of the two days, quite accurate mean temperatures for the interval through which the rate extended might have been formed. But, for the purpose in hand, it was thought sufficient to simply consider the algebraical mean of the mean temperatures of the two days between which the rate was taken as the temperature on which the rate depended. In general, this device has answered exceedingly well, though some cases occurred in which *a priori* a first-class representation could not be expected. Thus—to take an extreme case—if the mean daily temperatures of three successive days had been 1) 50° 2), 40° 3), 50°, the temperature corresponding to the rate from the first to the second day would have been 45°, and that from the second to the third would have been the same, so that part of the effect of the sudden changes in temperature would have been lost by this combination. On examination it was found that all the larger residuals could be explained from this, or similar circumstances. The same remarks apply to the formation of the term B.

The time-factor and barometer-coefficient are, in most chronometers, very small, in some cases hardly appreciable.

From an investigation of several chronometers Dr. J. HILFIKER (*l'influence de la pression de l'air sur la marche des chronomètres, extract du bulletin de la société des sciences naturelles de Neuchâtel, tome xvii*) finds the barometer-coefficient to vary from $-0^s.01$ to $+0.04$ per $\frac{1}{10}$ inch. Although the average time-factor in our case was found to be comparatively small, it is clear from the manner in which t and B were formed that the results obtained for a and c must be extremely uncertain. The chief object of the preliminary reductions, however, namely, the approximate determination of the temperature-coefficient, has been very satisfactorily attained. It was found that *the rate of the chronometer changes* $16^s.2$ *during one day, if the temperature changes one degree during the same interval.* It may be interesting to compare this result with others, as, for example, with those M. GUSTAVE CELLÉRIER (*étude numérique des concours de compensation de chronomètres, etc., mémoires de la société de physique et d'histoire naturelle de Genève, tome xxix,*) who has made extensive investigations in this connection. The temperature-coefficients given by him for various chronometers range between 9^s and 10^s. These rates of uncompensated chronometers are extremely large, and our

greatest admiration is due to the skillful inventors who, by proper compensation, have been able to reduce the rates to quantities which are insensible as compared with the foregoing.

On the hypothesis that our chronometer is a sidereal chronometer, the zero-point—i. e., the temperature for which the chronometer has no rate whatever, places itself at 54°.7. Accordingly, if we consider the chronometer to give mean solar time, the zero-point will be 69°.2. I reserve a more complete discussion to some future time, when the final results shall have been attained.

BERKELEY, CAL., March, 1891.

THE SYSTEM OF THE STARS.*

BY GEORGE E. HALE.

The rise and progress of Stellar Astronomy have been so rapid that, of necessity, its literature is almost wholly confined to the papers scattered through the publications of observatories and the various astronomical journals. It is, therefore, pleasant to find a large amount of this material collected together into a single volume, and entertainingly woven into a connected narrative. There are few observations or theories of importance within the range of her work which Miss CLERKE has not touched upon, and, though at times she rather summarily dismisses views at variance with her own, it may be said, in general, that opinions of any weight are accorded reasonable recognition. The plan of the book is to lead by gradual steps from the individual to the general, passing from single stars and nebulæ to double and multiple systems, and reaching, finally, the crowning problem of the construction of the heavens.

The first chapter brings forcibly before the mind the unbounded scope of astronomical investigation in a general account of the number and distribution of the stars, and devotes, in passing, considerable space to an explanation of scintillation. In the second chapter the methods of research are briefly pointed out, and the recent important developments of stellar photometry, photography and spectroscopy are clearly described. "Sirian and Solar Stars" form the subject of the third chapter, and here we are

* The System of the Stars; by Miss AGNES M. CLERKE, London, 1890, 8vo.